A Toolkit of the Stop Search in its Chargino Decay

Yang Bai

University of Wisconsin-Madison

Snowmass Energy Frontier Workshop@BNL

April 4, 2013

My Collaborators

Hsin-Chia Cheng

Jason Gallichhio

Jiayin Gu

YB, Cheng, Gallichhio, Gu, 1203.4813, JHEP 1207 (2012) 110

YB, Cheng, Gallichhio, Gu, 1204.xxxx, to appear

Main Message

The most important thing for searching for new physics:

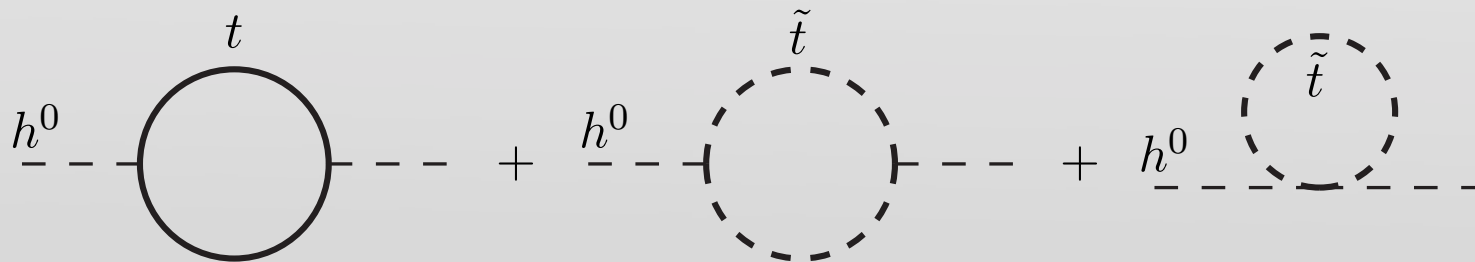## Understanding the Background

Motivation from a Natural SUSY

Do we have a natural theory for a light Higgs boson?

(1) Higgs boson as a pseudo-Goldstone boson

(2) Add additional particles to cancel the SM particle radiative corrections to the Higgs boson mass

in little Higgs models: top-partner (a fermion)

in MSSM: stop, sbottom, ...

Direct Production of Stops

The signal is ttbar+MET

|	
Early work:	......
	Meade and Reece, hep-ph/0601124
	Kong and Park, hep-ph/0703057
	Han, Mahbubani, Walker, Wang, 0803.3820
	......
Endpoints:	YB, Cheng, Gallichio, Gu, 1203.4813
	Killic and Tweedie, 1211.6106
Spin-correlations:	Han, Katz, Krohn, Reece, 1205.5808
Top-tagging:	Plehn, Spannowsky, Takeuchi, 1205.2696
	Kaplan, Rehermann, Stolarski, 1205.5816
	Dutta, Kamon, Kolev, Sinha, Wang, 1207.1893
Shapes of missing Et:	Alves, Buckley, Fox, Lykken, Yu, 1205.5805
Topness:	Graesser and Shelton, 1212.4495
	......

Search for Vanilla Stops

$$m_{\tilde{t}_1} \gg m_t + m_{\tilde{\chi}_1^0}$$

The signal is ttbar+MET (one lepton + jets + MET)

The leading background is ttbar in the dileptonic channel

TABLE I: Summary of expected SM yields including statistical and systematic uncertainties compared with the observed number of events in the signal region.

Source	Number of events
Dilepton $t\bar{t}$	62 ± 15
Single-lepton $t\bar{t}/W$+jets	33.1 ± 3.8
Multi-jet	1.2 ± 1.2
Single top	3.5 ± 0.8
Z+jets	0.9 ± 0.3
Dibosons	0.9 ± 0.2
Total	101 ± 16
Data	105
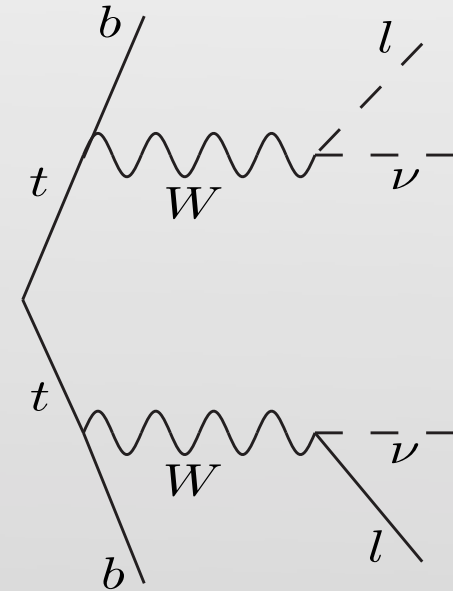
ATLAS Collaboration, 1.0/fb @ 7 TeV, 1109.4725

Reduce the ttbar Background

$$M_{T2}^W = \min\left\{ m_y \text{ consistent with: } \left[\begin{array}{l} \vec{p}_1^T + \vec{p}_2^T = \vec{E}_T^{\text{miss}}, \ p_1^2 = 0, \ (p_1 + p_\ell)^2 = p_2^2 = M_W^2, \\ (p_1 + p_\ell + p_{b_1})^2 = (p_2 + p_{b_2})^2 = m_y^2 \end{array} \right] \right\}$$
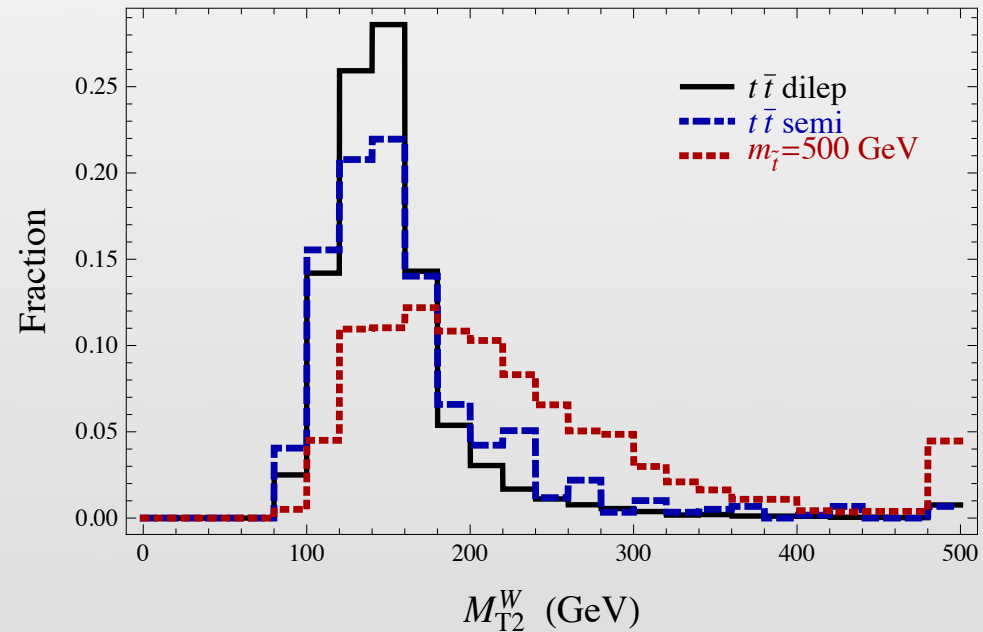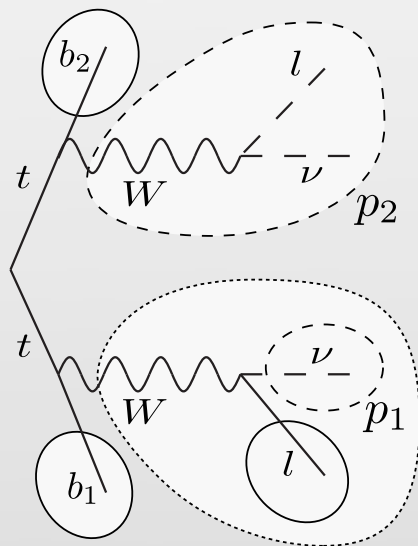
see Michael Graesser's talk for the "topness" variable and a comparison

7

Reduce the ttbar Background

| | Minimum Cuts | | | | | $m_{\mathrm{stop}} = 600\,\mathrm{GeV}$ | | |
E_T^{miss}	m_{eff}	M_{T2}^W	M_{T2}^b	M_{T2}^{bl}	$S_{20fb^{-1}}$	$B_{20fb^{-1}}$	S/B	σ
(150)	-	-	-	-	16.7	738.4	0.02	0.60
377	-	-	-	-	4.5	3.0	1.49	2.04
345	696	-	-	-	6.1	6.3	0.97	2.05
337	727	168	-	-	5.9	3.0	2.01	2.66
337	726	-	-	168	5.8	2.7	2.17	2.69
333	740	-	157	-	5.3	2.1	2.59	2.73
332	741	168	148	91	5.5	2.1	2.67	2.81

The ATLAS group has obtained our c++ code of variables and performed a search using our method

Motivated ATLAS Search

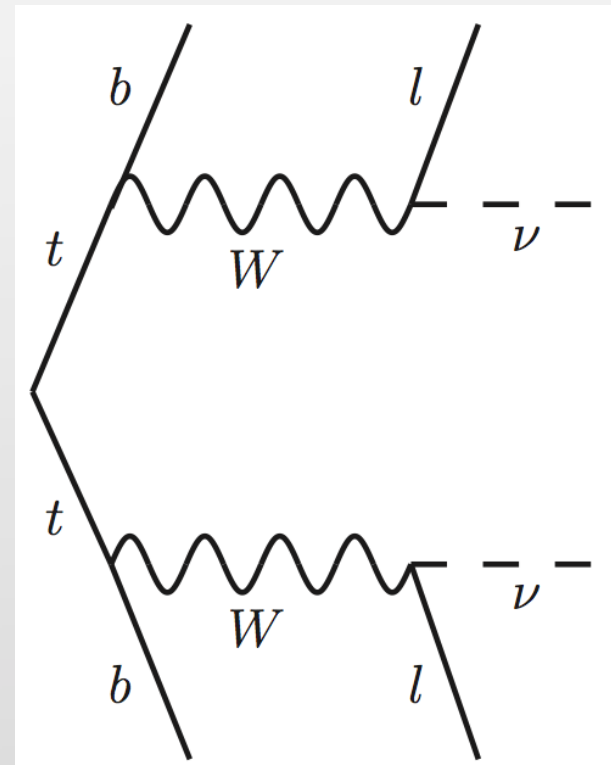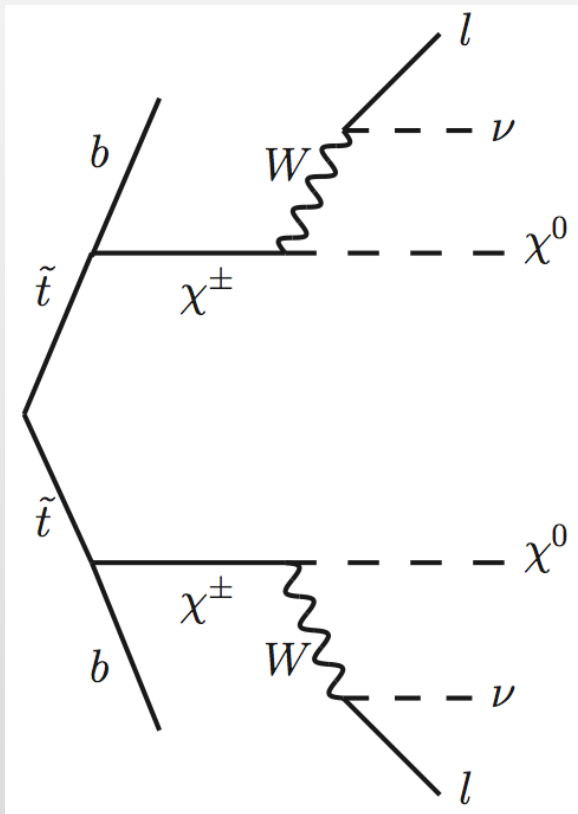ATLAS Collaboration, ATLAS-CONF-2013-037
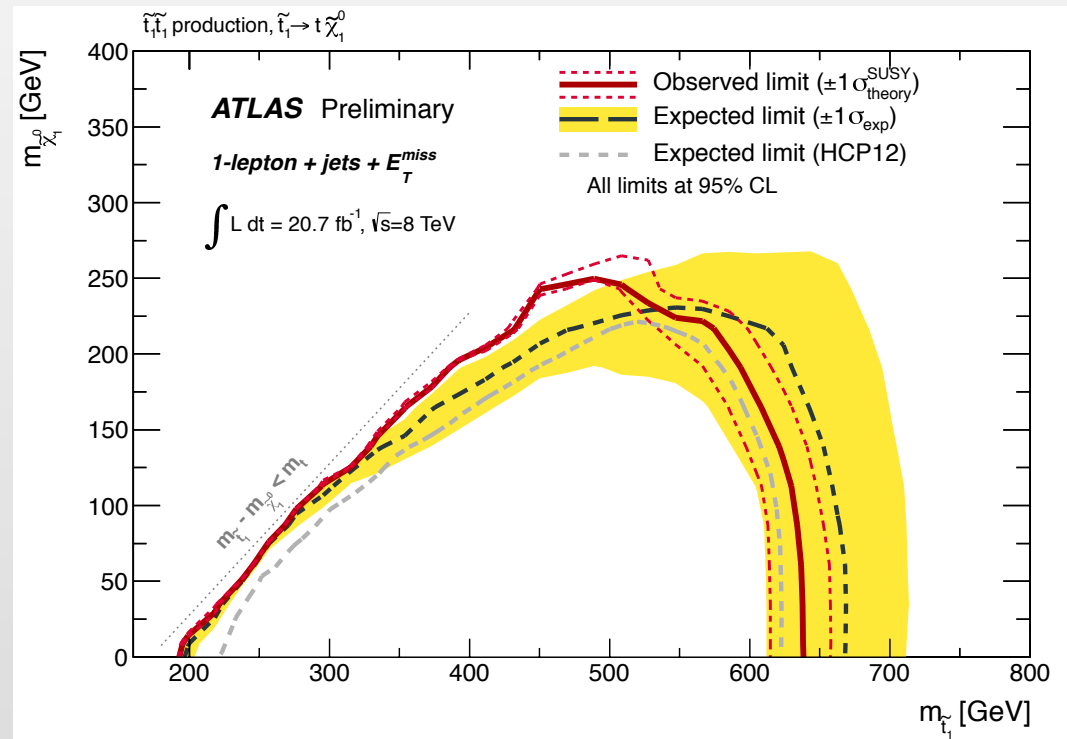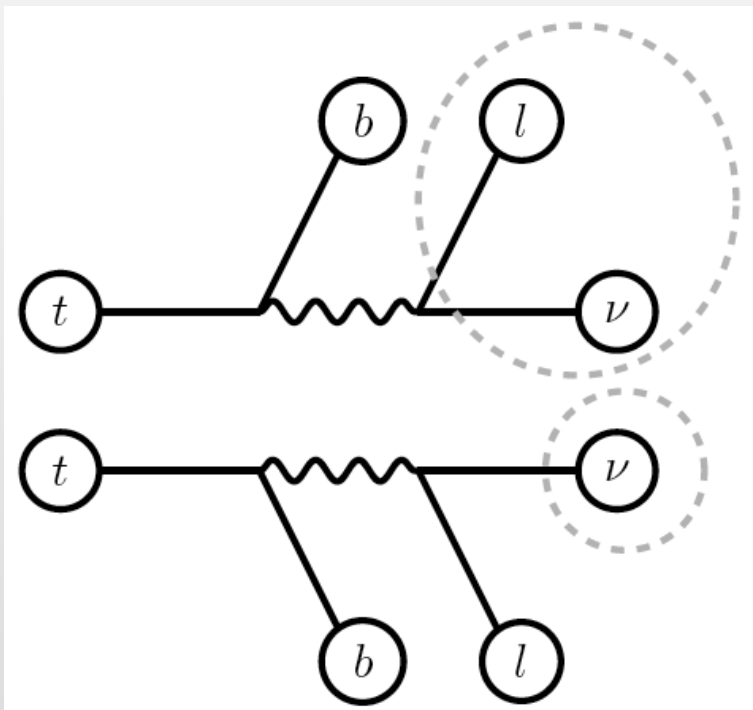
Extended ATLAS Search

ATLAS Collaboration, ATLAS-CONF-2013-037
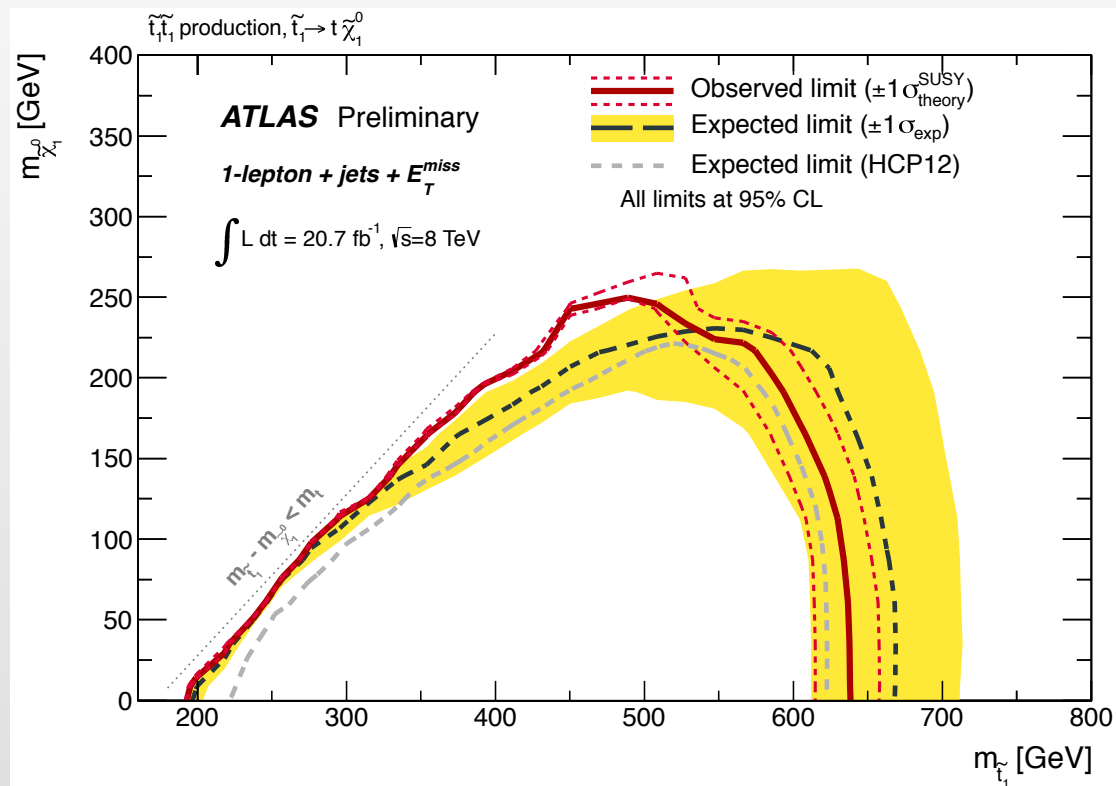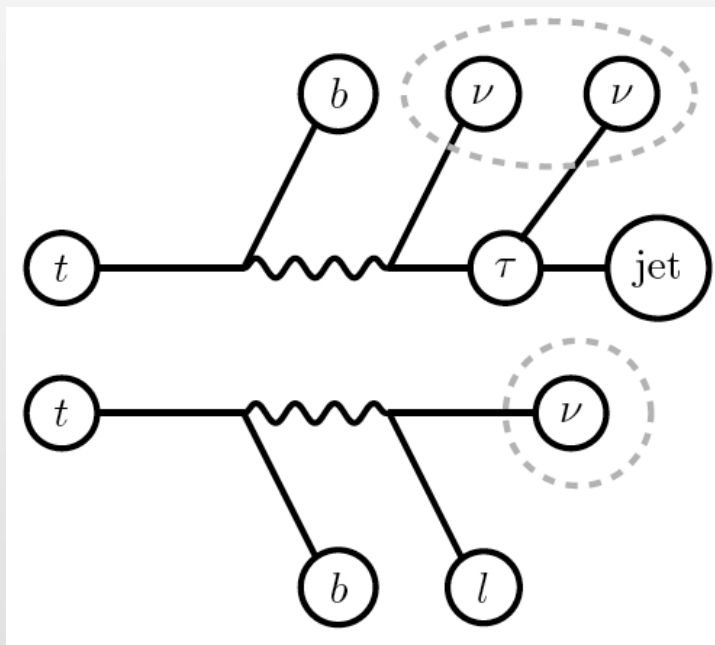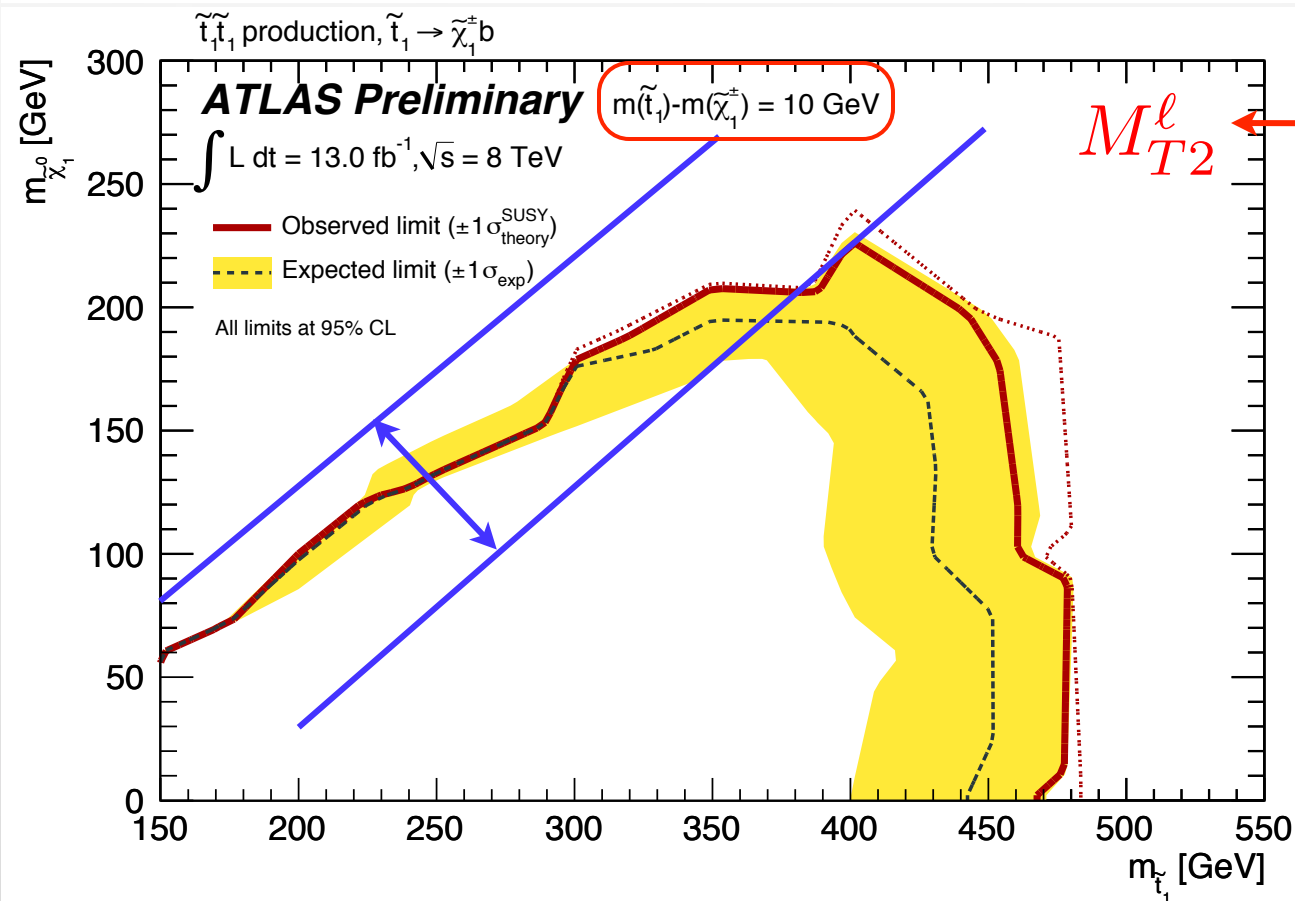

Experimentalists know backgrounds better than theorists

Stop+Chargino+Neutralino

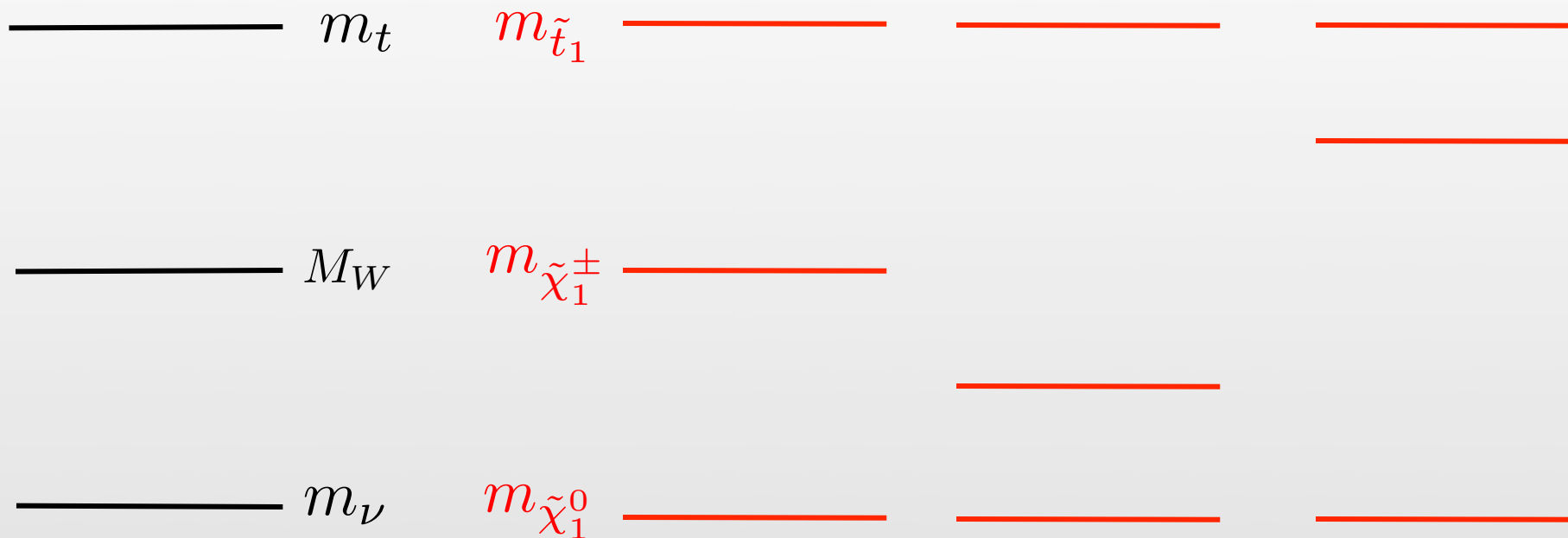$$m_W \lesssim m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \lesssim m_t$$

Current Status (two-lepton)

A Sample of Spectra

m_t $m_{\tilde{t}_1}$

M_W $m_{\tilde{\chi}_1^\pm}$

m_ν $m_{\tilde{\chi}_1^0}$

compared to the mass splittings in the ttbar background
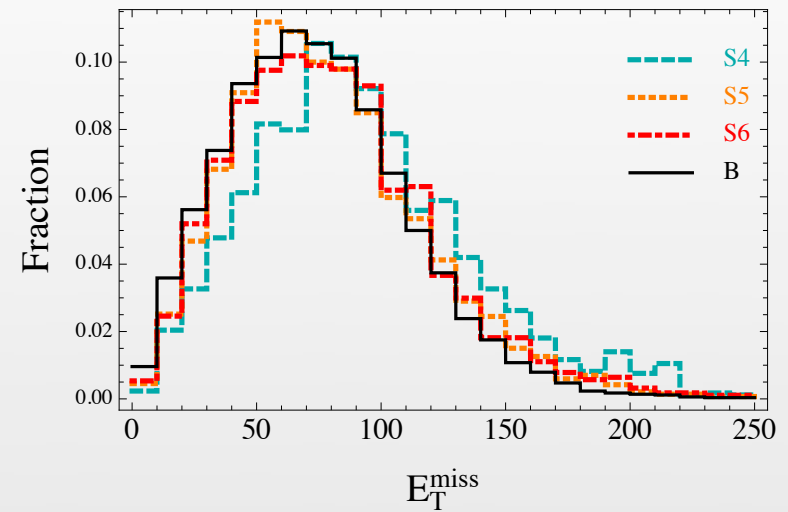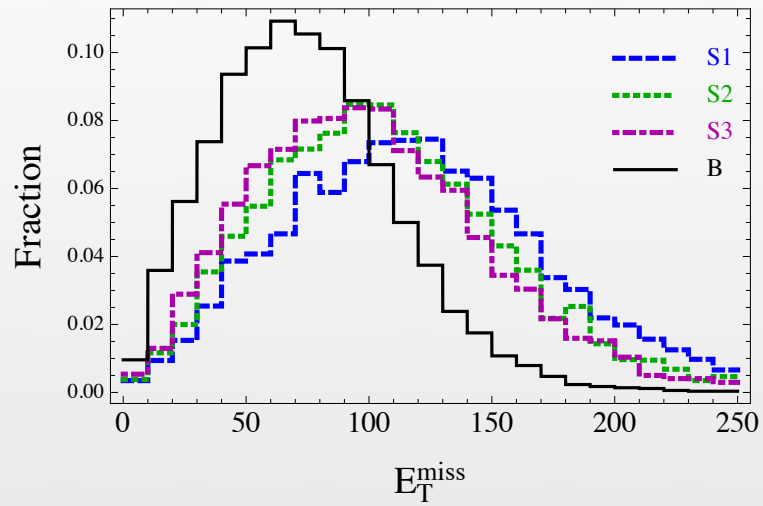
$$m_t - M_W \qquad\qquad M_W - m_\nu$$

A Sample of Spectra

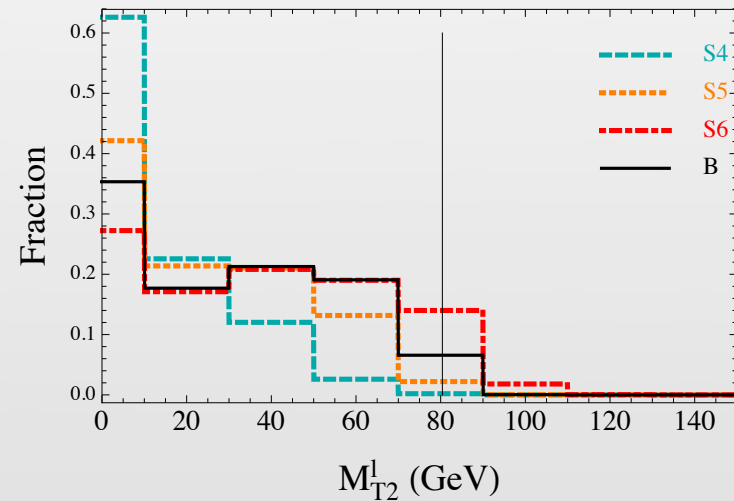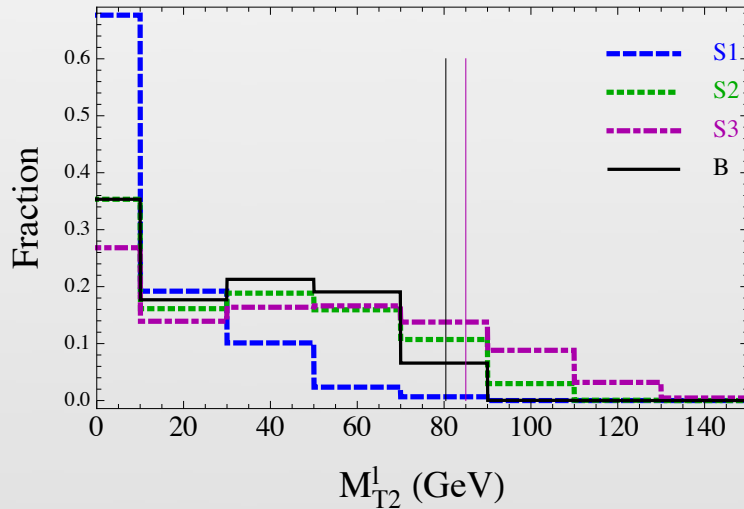|	$m_{\tilde{t}_1}$ (GeV)	$m_{\tilde{\chi}_1^\pm}$ (GeV)	$m_{\tilde{\chi}_1^0}$ (GeV)	b-jets	leptons
S1	300	160	120	harder	softer
S2	300	200	120	comparable	comparable
S3	300	230	120	softer	harder
S4	250	160	120	comparable	softer
S5	250	180	120	softer	softer
S6	250	200	120	softer	comparable

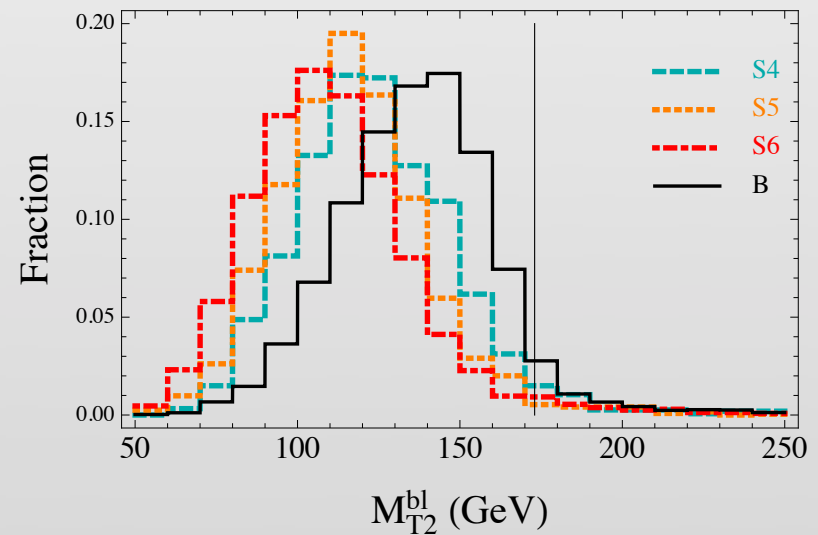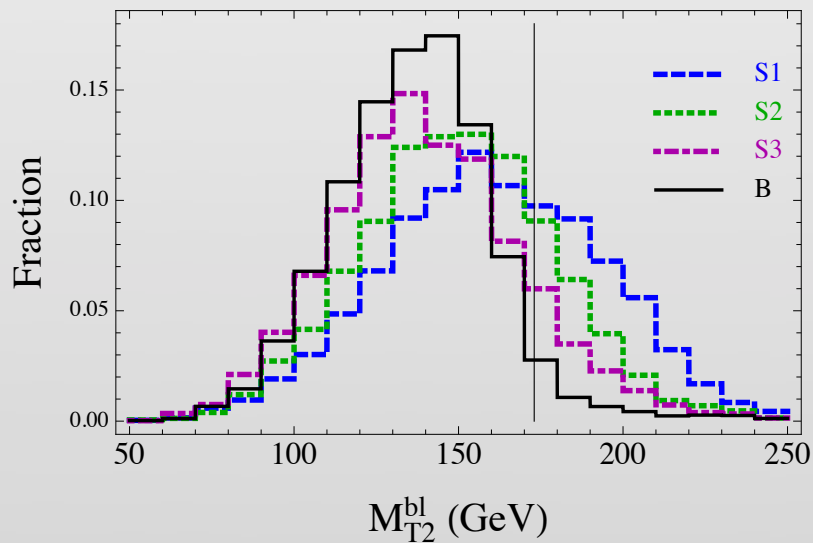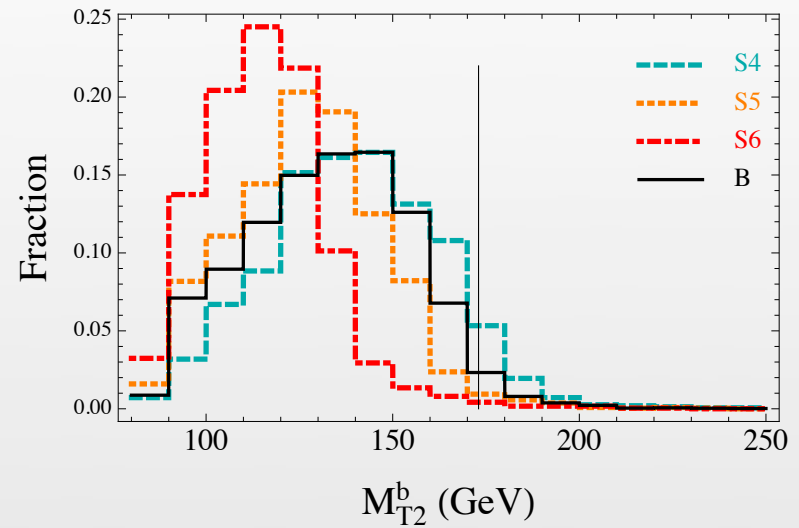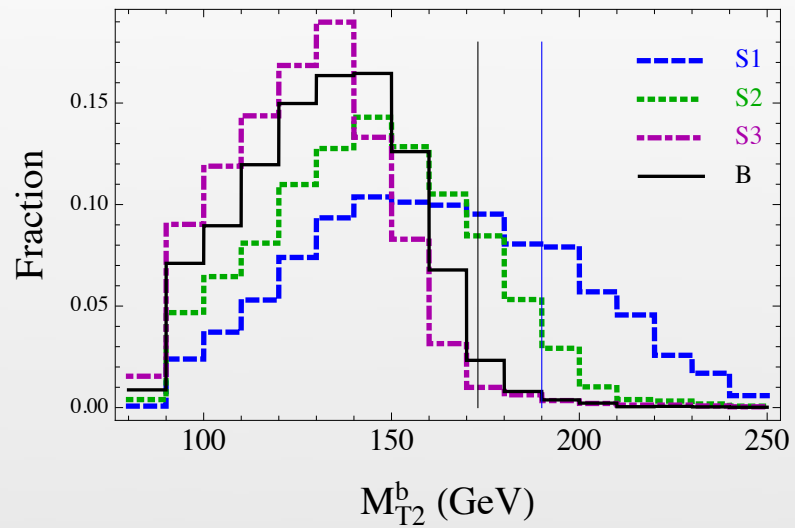Now, look for variables to improve the search

Basic Variables
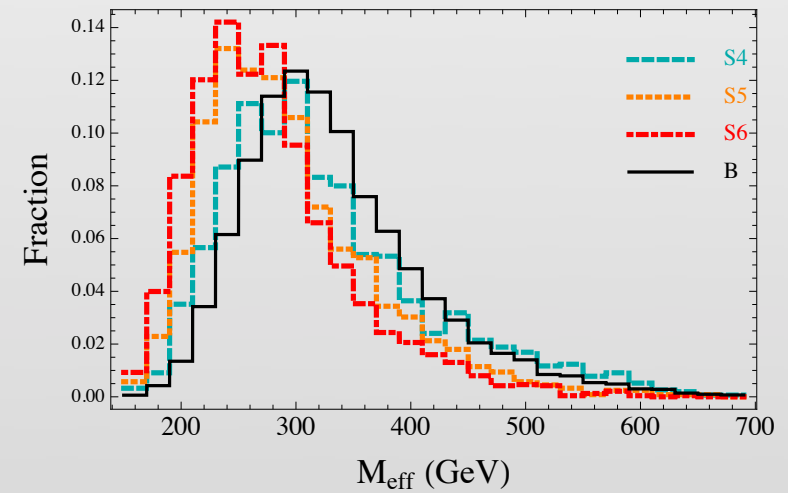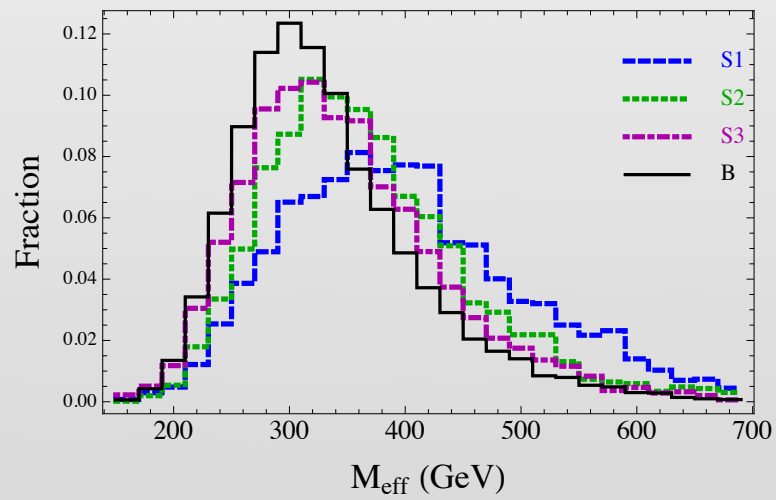
MT2 Variables

$$M_{T2}^{\ell} = \min \left\{ \bigcup_{\mathbf{p}_1 + \mathbf{p}_2 = \mathbf{p}_T^{miss}} \max \left[m_T(\mathbf{p}_T^{\ell_1}, \mathbf{p}_1), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{p}_2) \right] \right\}$$

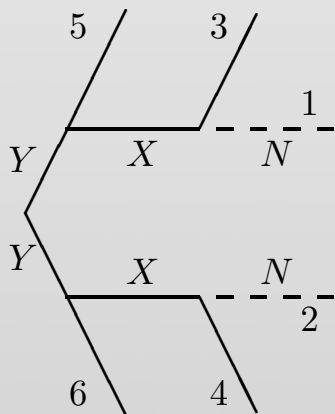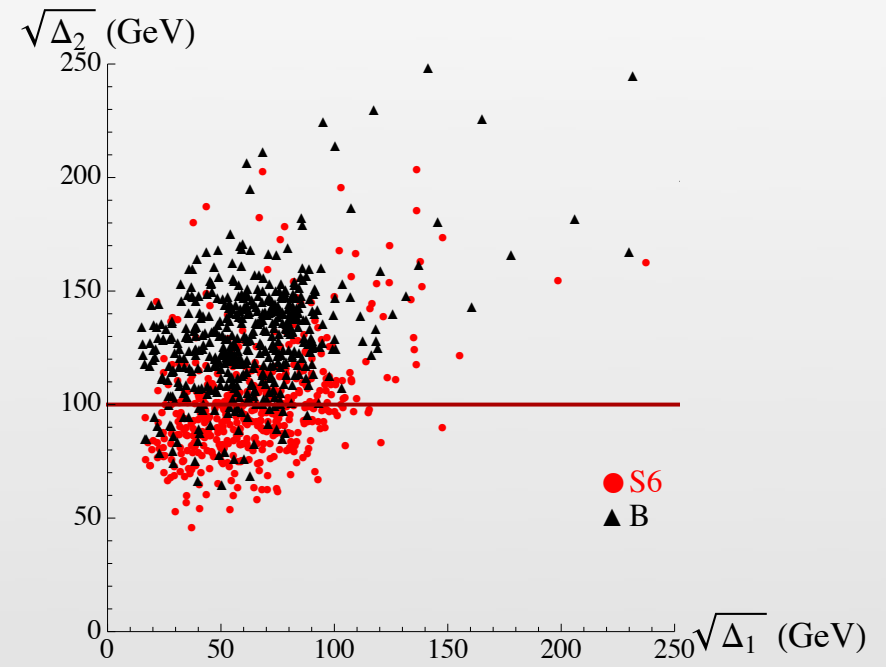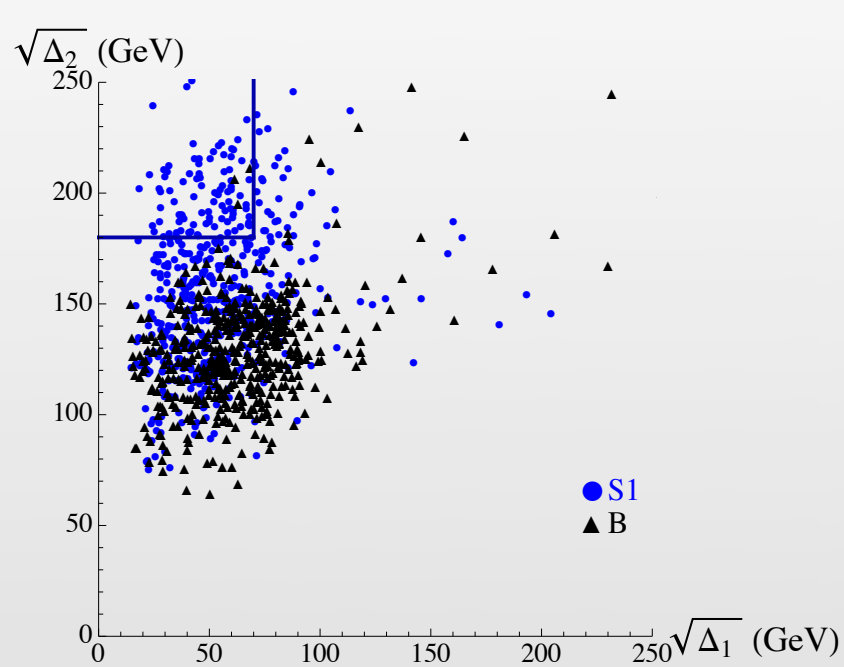Imposing a lower limit cut on the lepton-MT2 may improve S2, S3 and S6, but can do harm on other spectra

MT2 Variables

Mass-Compatible Variables

Use all the mass on-shell conditions

$\sqrt{\Delta_2}$ (GeV)

● S1
▲ B

$\sqrt{\Delta_2}$ (GeV)

● S6
▲ B

$\sqrt{\Delta_1}$ (GeV)

$\sqrt{\Delta_2}$ (GeV)

$\sqrt{\Delta_2}$ (GeV)

$$\Delta_1 \equiv m_X^2 - m_N^2$$
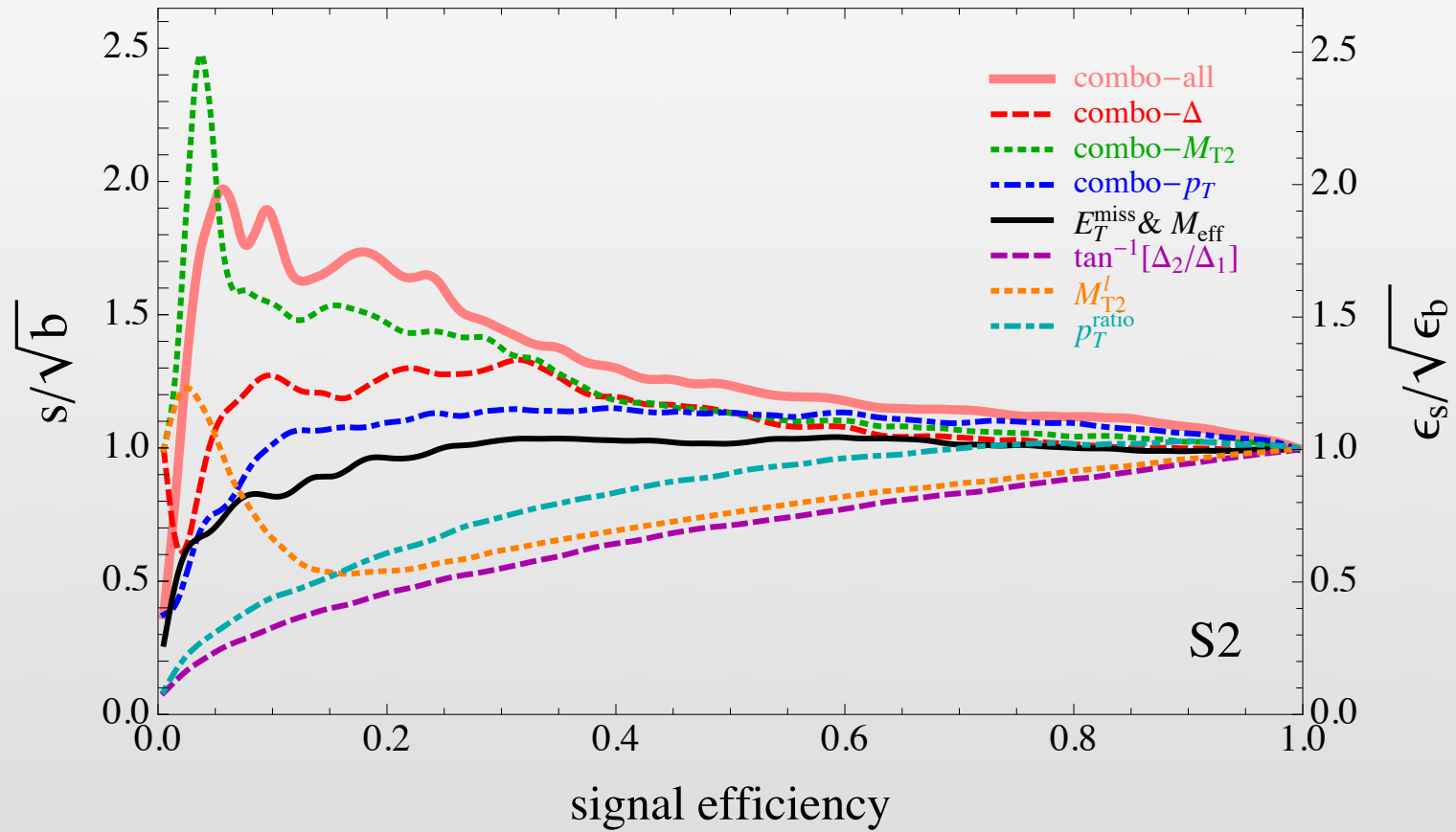$$\Delta_2 \equiv m_Y^2 - m_X^2$$

18
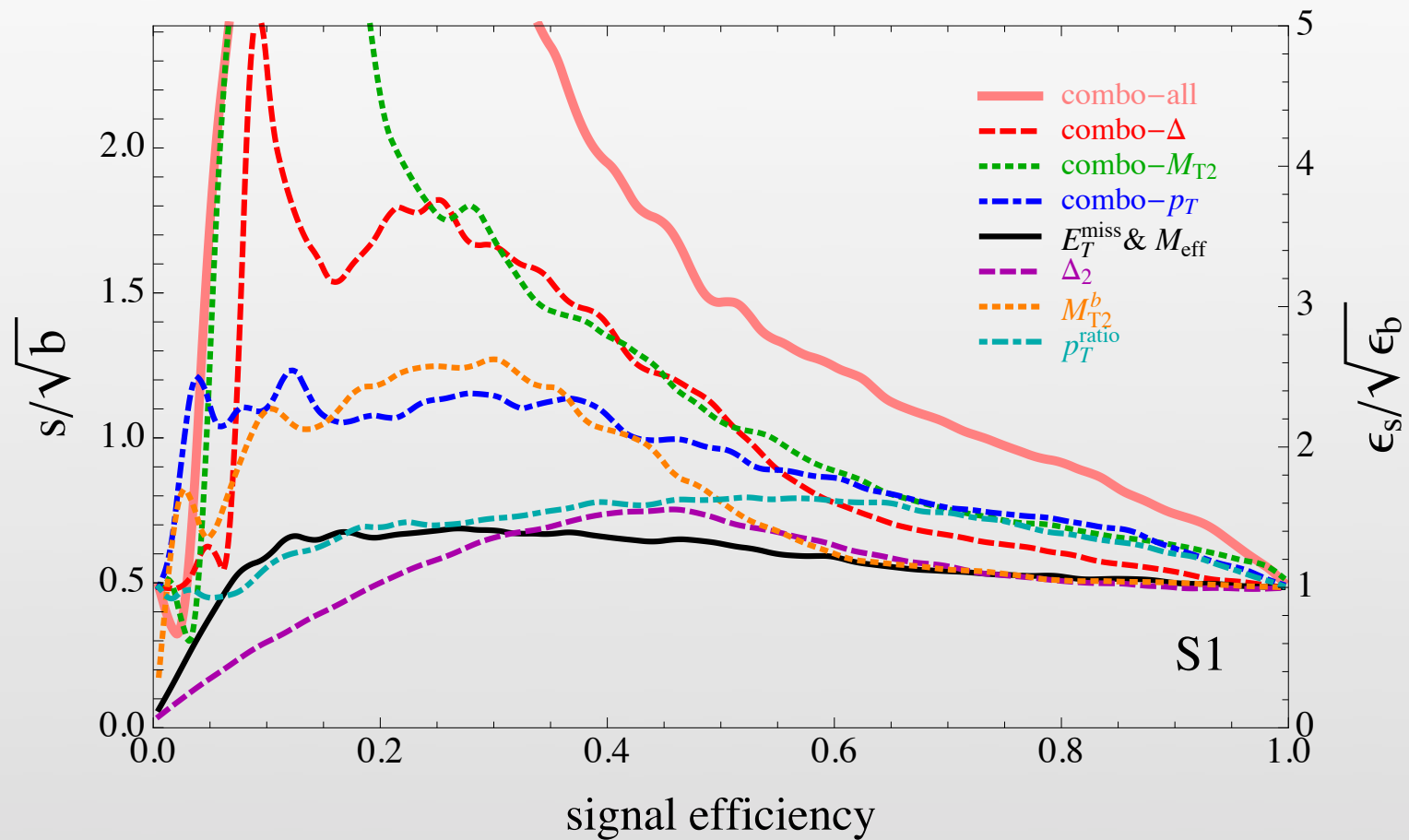
Performance -- S1
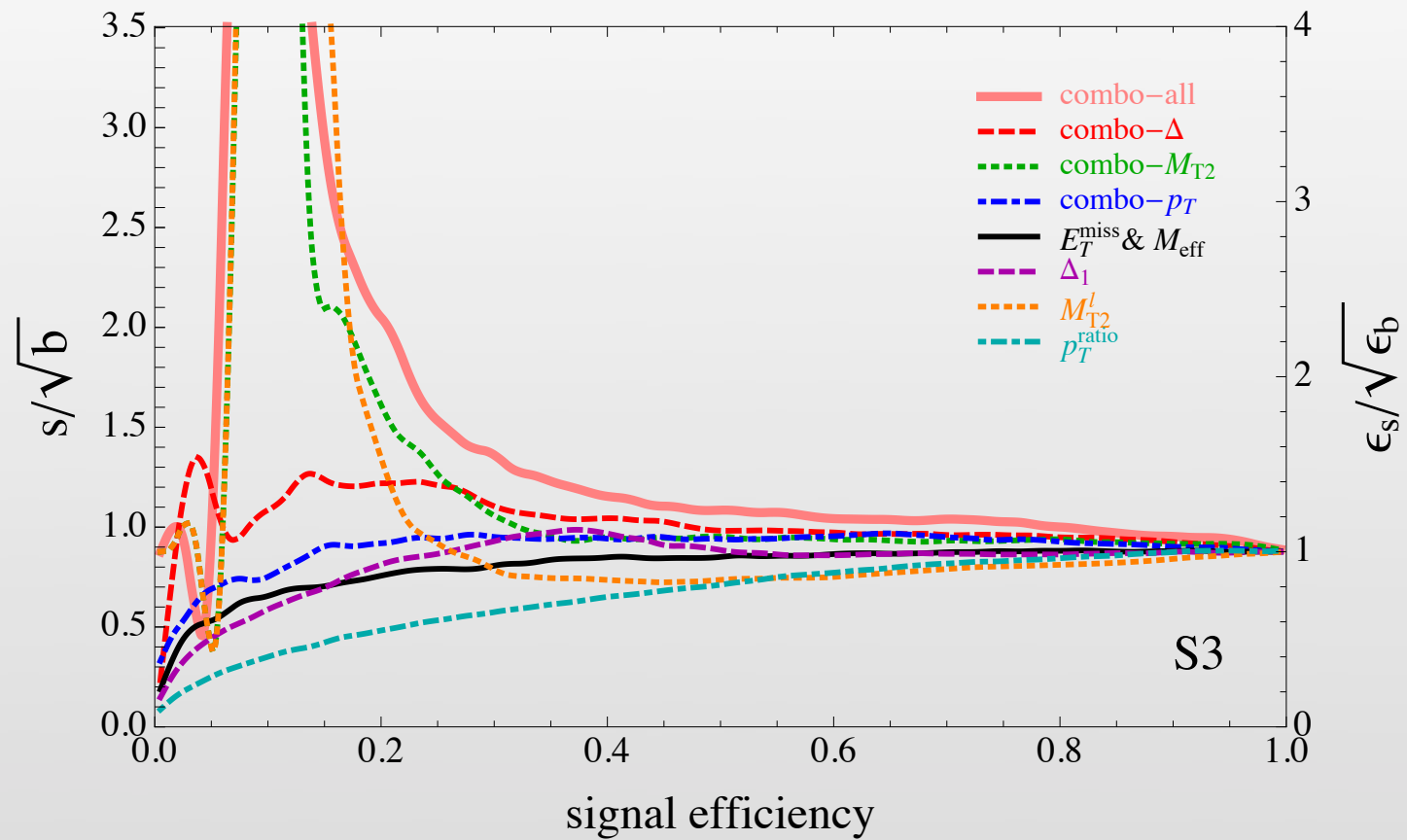

Throw events into a black box: Boost Decision Tree

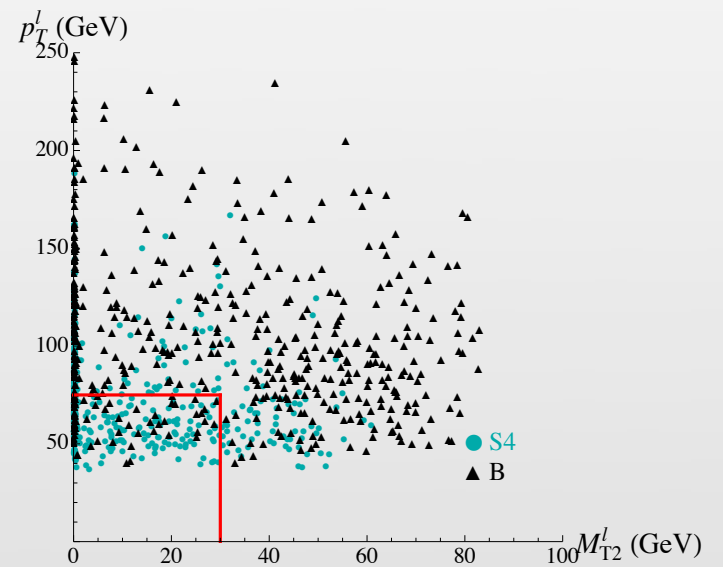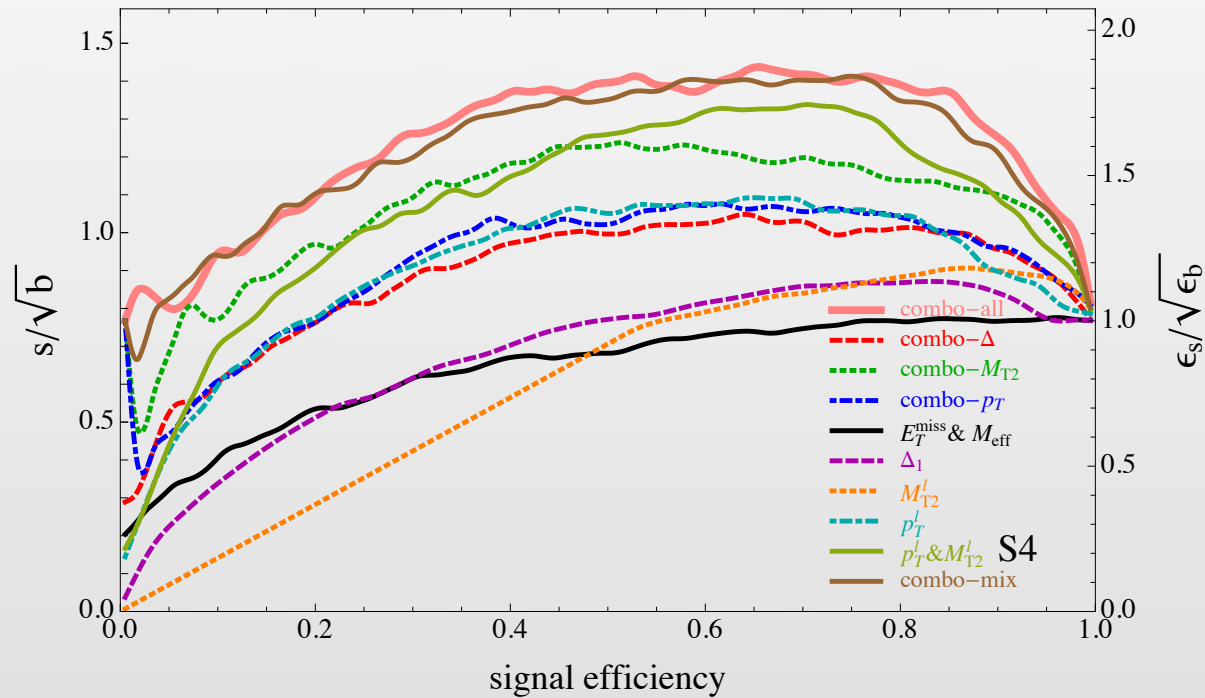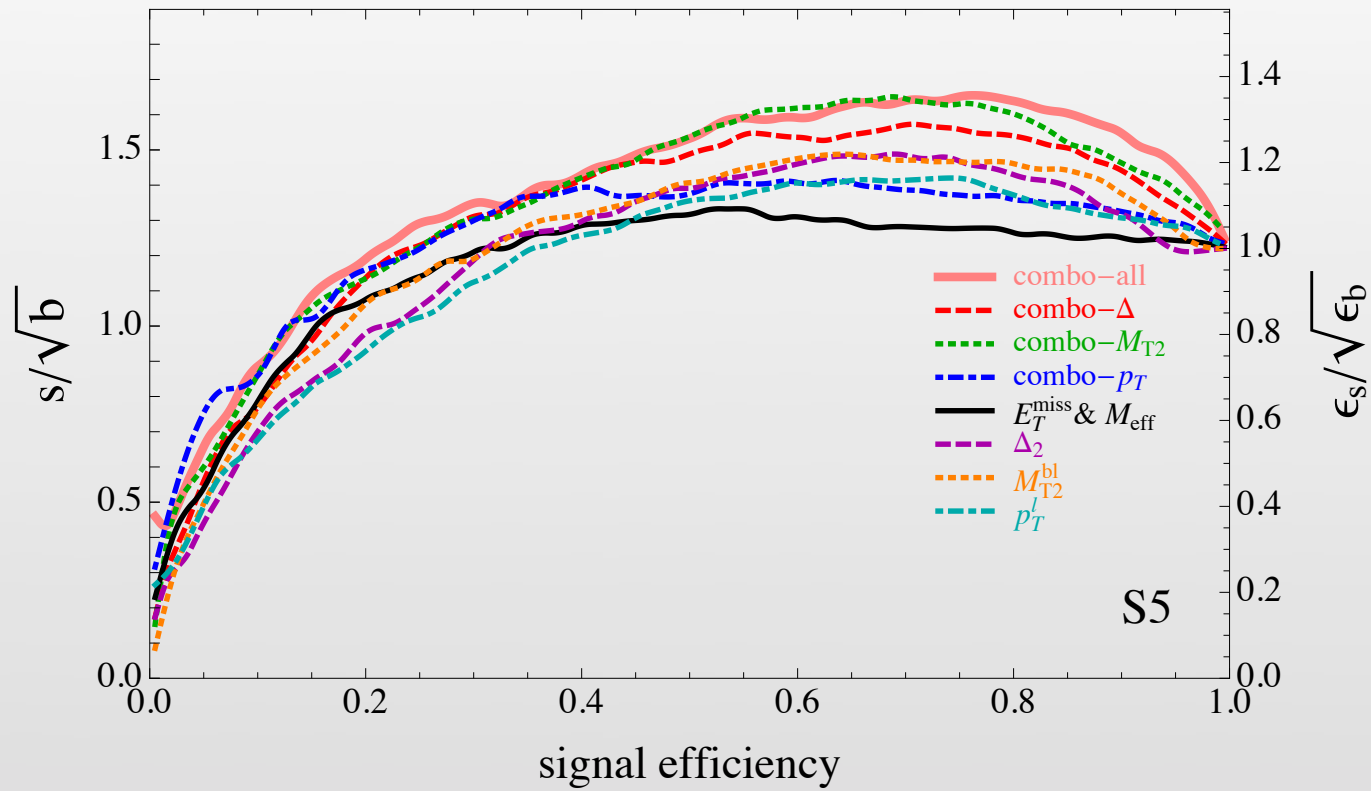# Performance -- S2

Performance -- S3

Performance -- S4

imposing upper limit cuts

Performance -- S5

Performance -- S6
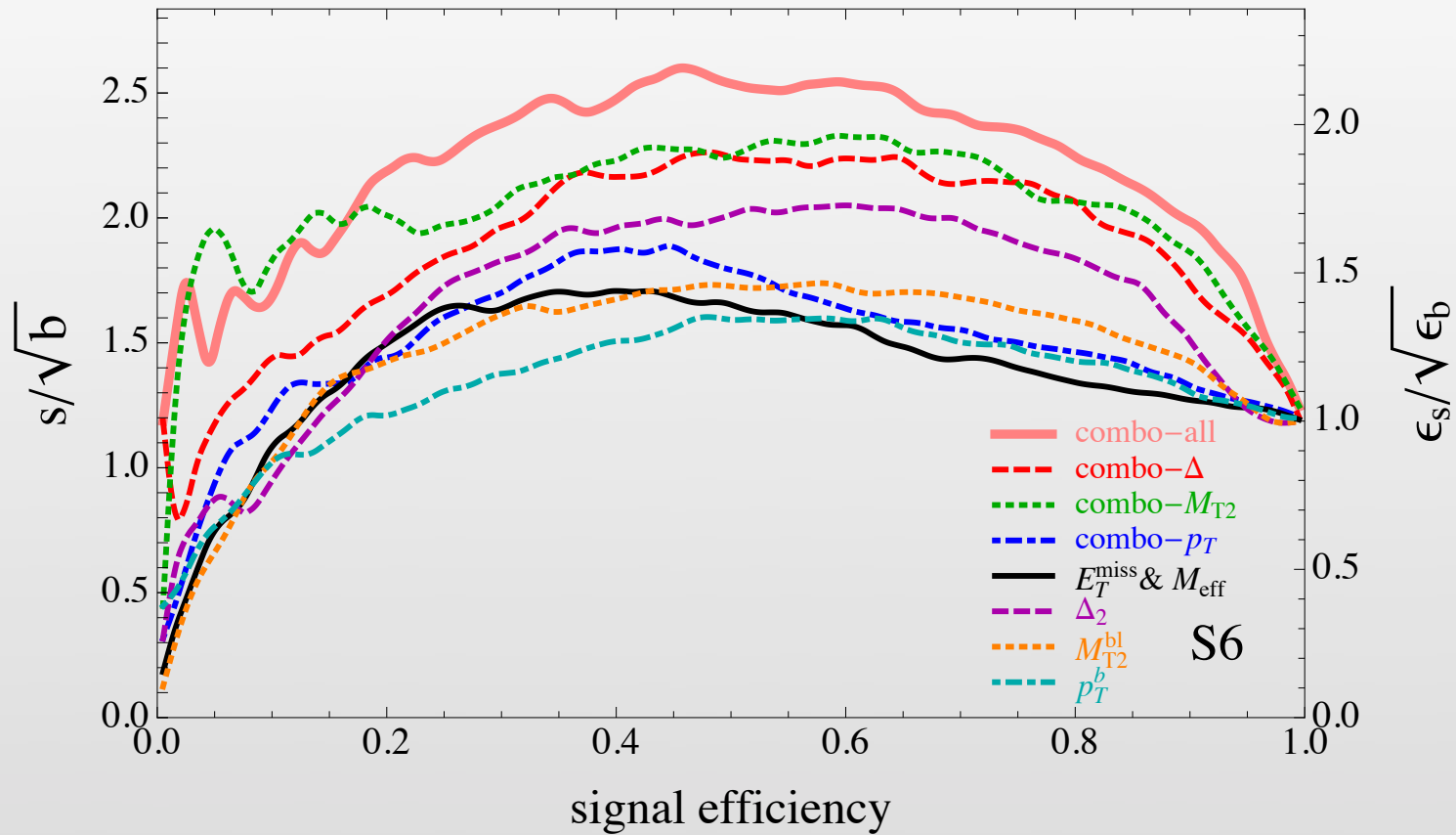
Performance Results

at 8 TeV LHC with 22/fb

	ϵ_s	ϵ_b	$\epsilon_s/\sqrt{\epsilon_b}$	s	b	$s/\sqrt{b}$	s/b
S1	0.405	0.0103	3.98	22.0	130	1.93	0.169
S2	0.175	0.0101	1.74	19.5	127	1.73	0.154
S3	0.225	0.0126	2.00	22.1	159	1.76	0.139
S4	0.655	0.122	1.87	56.4	1540	1.44	0.0366
S5	0.765	0.318	1.36	105	4009	1.65	0.0261
S6	0.455	0.0432	2.19	60.6	544	2.60	0.111

A Summary of Best Variables

	$m_{\tilde{t}_1}$ (GeV)	$m_{\tilde{\chi}_1^\pm}$ (GeV)	$m_{\tilde{\chi}_1^0}$ (GeV)	b-jets	leptons	best-variables
S1	300	160	120	harder	softer	M_{T2}^b
S2	300	200	120	comparable	comparable	combo-all
S3	300	230	120	softer	harder	M_{T2}^ℓ
S4	250	160	120	comparable	softer	$p_T^\ell + M_{T2}^\ell$
S5	250	180	120	softer	softer	combo-all
S6	250	200	120	softer	comparable	Δ_2

You can download the cpp code of variables via:

https://sites.google.com/a/ucdavis.edu/mass/

Thanks

Current Status (One-lepton)

ATLAS Collaboration, ATLAS-CONF-2013-037